

CANE TECHNIQUE: TOWARD MORE COMPLETE
PATH COVERAGE

BY
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INTRODUCTION

For many of the blind, the safety and orientation necessary to self-reliant travel depends on skillful use of the cane. Clear path-scanning is the cane's primary insurance of the blind walker's safety. One of the greatest shortcomings of the cane's simple system, that it leaves the upper body vulnerable to low overhangs, does not always detract seriously from its effectiveness, for such overhangs rarely obstruct pedestrian walkways. The cane's virtue as an orientation tool is less apparent than its protective value. Perhaps a summary of Leonard's (1970) description of the cane as an environmental sensor best describes its aid to orientation: the inquiring cane tells its user about the boundaries of his path and describes for him the nature of the objects he encounters as he follows it or prepares to leave it. The cane's probing allows the blind walker to detect and distinguish a narrow break in the margin of a grass-lined sidewalk from a wider driveway entrance. The cane's touch familiarizes the blind pedestrian with many objects otherwise beyond his discernment and assists his sense of direction by increasing his catalogue of perceptible, reliable landmarks. The cane thus assists its user in keeping to the route he wishes to follow and greatly diminishes the danger of his colliding with impediments in his path.

The cane's benefit as an obstacle-detector depends on the way in which the cane-user explores the path of travel. To study cane-scanning

effectiveness, one must examine the dynamic relationship between walking and cane technique. Since patterns of walking and cane-handling vary from one individual to another, analysis of this relationship is by no means easy or trivial. A logical approach to the problem, and the purpose of this thesis, is to begin by examining the most basic unit of cane-walking, the step. From the simplest description and measurement of the step, examination will turn to measurement of the specific characteristics and requirements of cane-traveling blind subjects. After measuring a blind subject's characteristics, a model of his optimally safe mode of cane travel can be described. Such an ideal model will be called the subject's "idealized step" -- a model that assumes perfect execution of the prescribed cane technique.

Subjects' real characteristics will be measured in order to estimate cane-scanning effectiveness for detecting obstacles. The obstacles this analysis will consider are such common ground-anchored and relatively high obstructions as sign-posts, lampposts, trees, and parking meters. Although many, if not most, common obstacles will be detected if the high pole is detected, this is not the case for impediments near ground level, especially the low pole of narrow diameter. For the sake of simplicity, this study will consider the path of travel free of low rising and slender obstructions. The study's diagnostic measurement of cane-scanning effectiveness must also depend on highly idealized walking and cane-handling. It does not, therefore, promise great reliability as a clinical tool. It will, however, offer a means for comparing and evaluating the effectiveness of conventional and unconventional cane-probing techniques.

Although such a paradigm falls outside the scope of this thesis, a cane-walking model might be designed to include widely varying, even extremely subtle, variations in walking patterns, cane techniques, and modes of obstacle detection. Combined with sophisticated methods for measuring walking and cane-handling, such a model could provide an invaluable clinical diagnosis of cane-scanning effectiveness.

Walking

Unlike running, an action requiring that the body remain instantaneously suspended in the air, walking is a form of locomotion which keeps a supporting leg in continuous contact with the ground. Walking has been described as a supported "hop" sustained at the moment of levitation by the opposite limb (Ducroquet, 1968); to represent the same picture more precisely, walking forms a series of "hops," in which the right limb crosses the weight-bearing left and then assumes the body's weight, freeing the left limb to "hop." Or the process of walking may be imagined as alternation between loss of balance and recovery of poise during weight-transfer from the rear to the forward foot -- an alternation occupying an interval of a fraction of a second (Godfrey and Kephart, 1969).

The stride length of a walker indicates the distance intervening between successive points of foot-to-floor contact made by one of his feet; a walker's step length represents the distance he covers between his right foot's initial touch and the successive touch of his left foot

(Murray, 1967). This thesis will measure both stride and step length from heel contact to heel contact.

Since literature on walking patterns has given small attention to the case of blind walkers, a review of pertinent literature must concentrate on the characteristics basic to the patterns of normal, seeing walkers. As a point of reference, the figure generally accepted as the stride length during normal walking is 60-64 inches; normal cadence varies from 90-110 steps per minute (Smidt, 1974; Peizer, Wright, and Mason, 1969). Normal adult subjects increase their walking speed by taking longer strides in shorter periods of time (Murray, 1967). Women walk more slowly than men because they take shorter strides (Murray, 1970); women shorten their stride and reduce their slower walking rate when they wear high-heeled shoes.

Studying the displacement patterns exhibited by sixty normal men walking in free cadence, Murray, Drought, and Kory (1964) have observed that forward motion stays nearly constant. Peizer et al (1969), corroborate the findings of Murray's group. Slightly more forward displacement occurs shortly after heel strike, during the instant of double-limb support, and slightly less forward displacement occurs during single-limb support. Measuring the vertical movement of walking, Murray et al (1964) and Peizer et al (1969) have demonstrated that, with each step, the body gently oscillates through a two-inch excursion from a vertical peak to a vertical valley.

Murray and his associates (1964) explain that

The low segments of the curve occur during double-limb support when one extremity is positioned obliquely forward and the other, obliquely backward. The high segments occur during single-limb support as the trunk rotates over the fixed foot (p. 349).

Gentle lateral fluctuations accompany the walking cycle's stages of single-leg support, as the walker's head alternately shifts toward each of the weight-bearing extremities. Murray et al (1970) have also noted that, although normal men and women follow similar patterns of motion, men's vertical, lateral, and forward excursions exceed those women undergo when walking.

The term "gait" includes the carriage, rhythm, and rate of walking. Miller (1967, 1969) states that normal gait requires the aid of sight. She explains, first, that vision enables the walker to gauge the timing of his heel strike by the demands of his terrain. Just before his heel strikes, the walker's center of gravity is in front of the opposite, supporting limb. To prevent disequilibrium, his heel strike must be precisely timed. When the walker cannot see to assess the ground surface, he cannot adapt the timing of his heel strike to the path before him; consequently, he cannot steady his gait, and he may completely lose his balance and fall. Second, because vision permits an accurate sense of the ground to be covered, it allows the correct adjustment of posture essential to equilibrium. The seeing walker's body responds immediately to what his eyes absorb; his posture changes to secure his balance by keeping his center of gravity over

his feet (Dickinson, 1968; Cratty, 1971). Unaided by the advantage of sight, the blind walker's balance relies on his posture's conformity to signals sent by the semicircular canals and the proprioceptive sense of the muscles and joints. Finally, Miller notes the protective function of sight. Vision's capacity for survey at long distances alerts the seeing walker to dangers or hindrances in time for defensive reaction; it thereby increases his security and reduces for him the sort of tension a blind walker must report when he comes, abruptly, upon perilous or frustrating obstructions he cannot discern from a protective distance.

Siegel (1966) writes that the proper dynamic posture of the blind walker is predicated on proprioceptive spatial orientation, postural reflex, and body image. Siegel considers the vertical dimension of proprioceptive spatial orientation most important to dynamic posture. The blind walker perceives the direction of gravity through his body's continuous pattern of adjustment to its pull. The position of the head determines his primary postural reflexes, the automatic reactions which coordinate axial and appendicular posture. Siegel also stresses the crucial influence of body image:

The image that the blind person has of his body in space, as it influences his perception and through this impression his mobility, can be conditioned adversely by set and adaptation. Emotional problems may further distort body image and mobility as the dynamic presentation of this image (p. 18).

Cane Technique

The touch technique is the method for walking with a cane conventionally chosen by specialists teaching orientation and mobility to the blind (Hill and Ponder, 1977; Hoover, 1950). The touch technique requires that the cane grip rest in the fleshy "trench" at the midline of the base of the palm; the back of the hand facing laterally. The wrist of the hand grasping the cane is centered at the midline of the body. The wrist pivots through flexion, extension, and hyperextension, then returns to flexion (see Figure 1a). The wrist revolution moves the cane tip to contact the ground at a point just lateral to each shoulder; at the zenith of the arc it describes, the cane tip just clears the ground. Correct, rhythmic manipulation times this arcuate movement so that the tip of the cane and the heel of the opposite foot contact the walking surface in unison (see Figure 1a). Those teaching orientation and mobility term the synchronous strike of cane tip and opposite heel "in-step." Completely reversing in-step synchrony so that the cane tip strikes with the heel of the near foot, the walker demonstrates "out-of-step." When the cane-user walks "out-of-phase," he has failed to achieve synchrony of cane tip and heel strike. Only rhythmically phased "in-step" correctly executes the touch technique, for it is thought that "in-step" alone protects the walker from hazards he needs advanced warning to avoid (Hoover, 1950; Hill and Ponder, 1976).



a.

Area
of no
Protection



b.

Figure 1. A photograph showing wrist motion in the touch technique (a.). An orthographic projection of the author's step in the touch technique showing areas of no protection (b.).

Using orthographic drawings, Uslan and Manning (1974) charted the path the moving cane projects on the ground. They isolated the variables crucial to successful touch technique: the length of the cane, the vertical distance between the cane hand and the ground during the cane's operation, and the length of the walker's step. Measuring his own step length, the height of his cane hand, and the length of the cane employed for an experimental walk through the touch technique, the author arrived at an orthographic projection of his own step shown in Figure 1b. As the illustration indicates, the cane does not scan the entire path of travel and, so, leaves the traveler to collide with any obstacles located in the areas it does not explore. The experiment helped substantiate Uslan and Manning's (1974) contention that the touch technique gives only imperfect aid under all but unrealistic circumstances: long cane length, short step length, and short height of the cane hand. To document cane-scanning effectiveness with greater accuracy requires calculating the percentage of a given path covered by a scanning cane. Appendix A records the formula and computer program derived to test coverage.

Systematic variation of each of the author's measurements yields graphs for percent path coverage versus cane length, height of cane hand, and step size (see Figure 2). The percentage of the path covered by the touch technique drops drastically when the cane is short and the cane hand relatively distant from the ground. As step

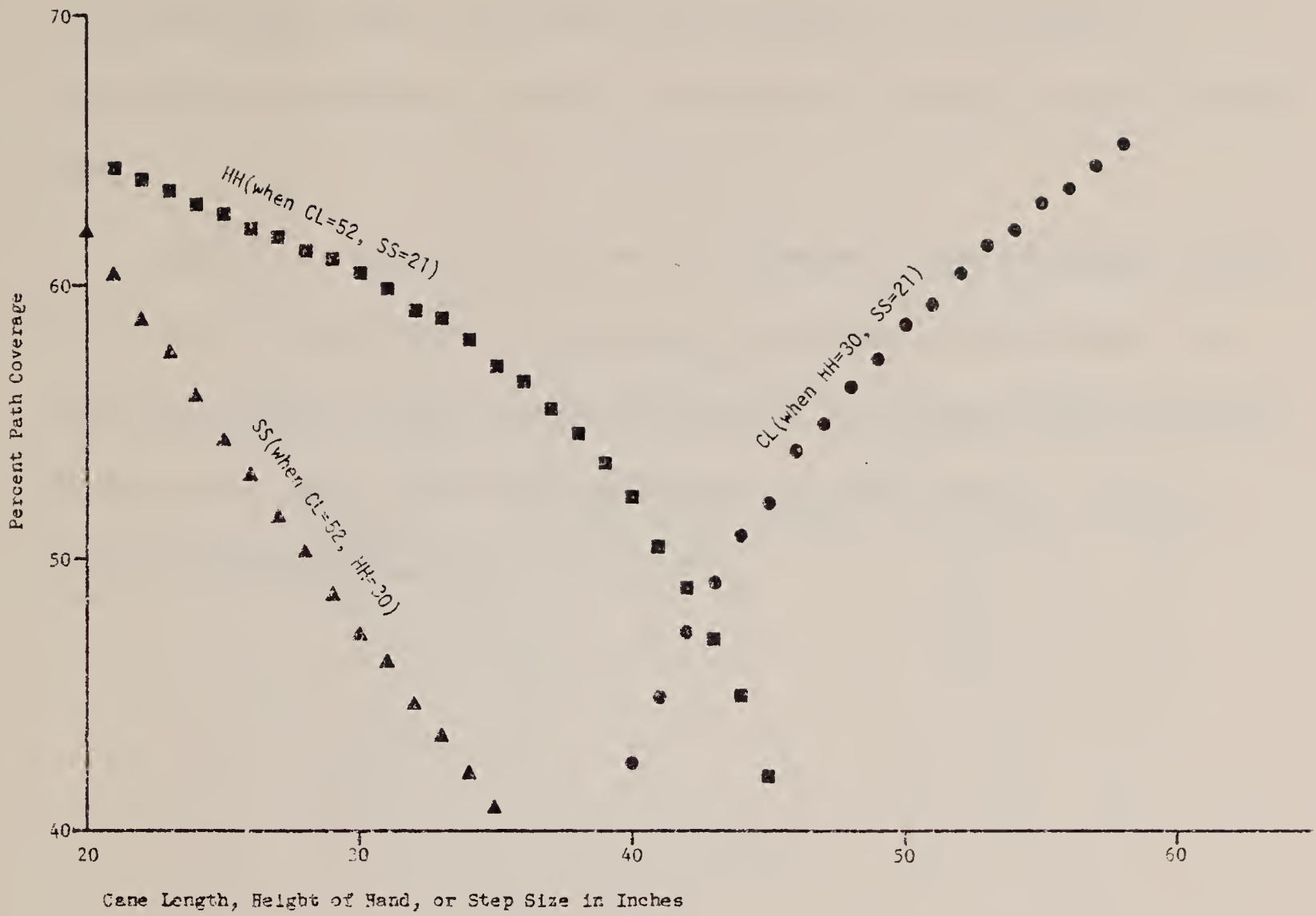


Figure 2. Percent path coverage versus cane length (CL), height of hand (HH), and step size (SS) for the touch technique.

size increases, path coverage diminishes almost linearly, at approximately 1.4 percent per inch. To improve any variable of the author's specifications results, at best, in coverage of seventy percent of the path.

Figure 3. compares the protection offered by the preferred pattern of in-step to the security furnished by unorthodox out-of-step. At the initial heel strike, out-of-step leaves the forward leg vulnerable; in-step does not. After the initial heel strike however, in-step gives no added protection.

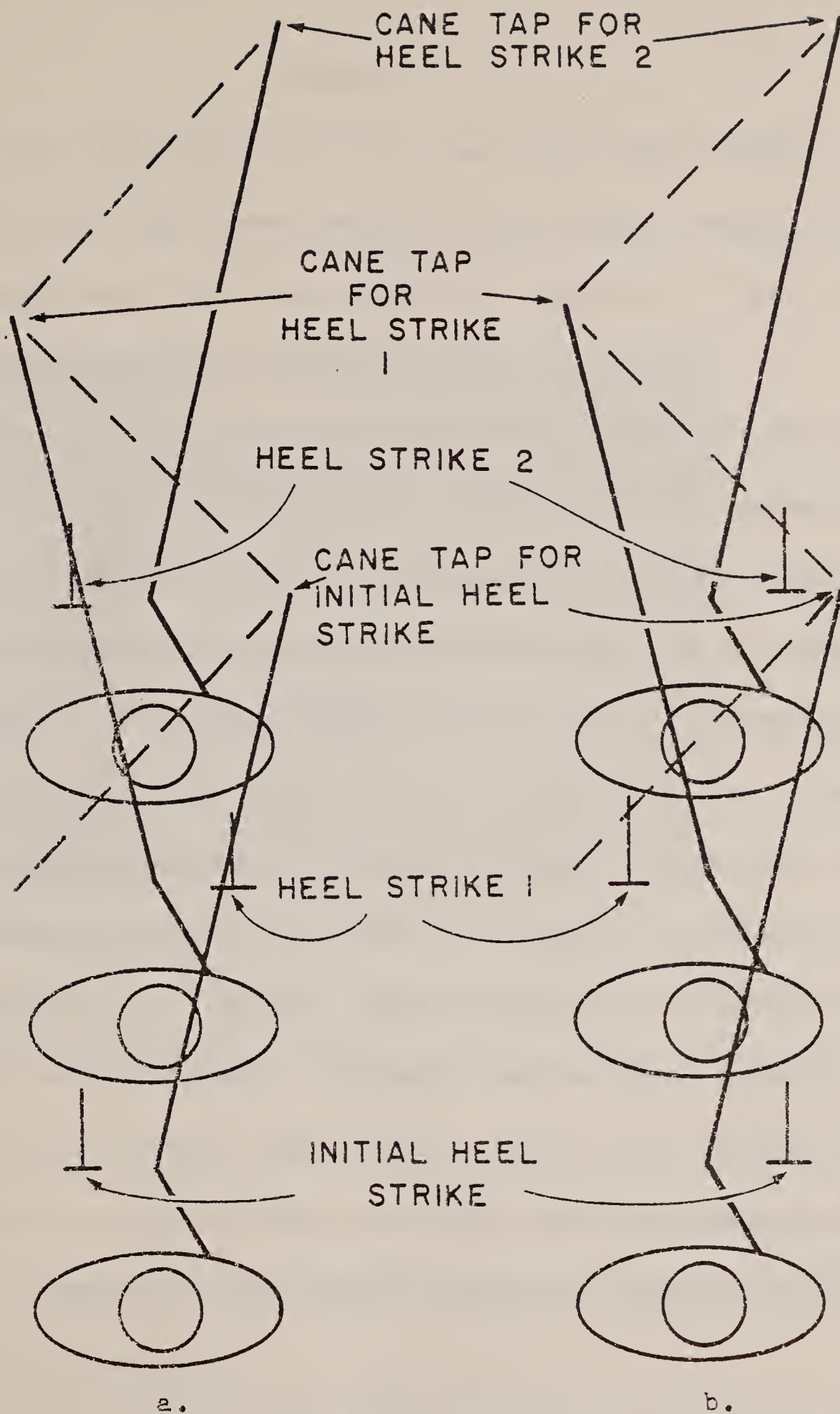


Figure 3. A comparison of cane tip/heel strike cadence for in-step (a.) and out-of-step (b.).

METHOD

The study collected data for all cane-using blind students at a school for the blind. Measurements of step length, height of cane hand, forearm length, and cane length were compiled. All but step length was measured with a measuring tape.

A specially constructed, portable pathway twenty-five feet long measured step length (see Figure 4.). Lateral switching runners were placed two inches apart along the pathway and a constant source of current was applied to one end to convert the path into an electrical ladder network. The voltage output of this circuit is proportional to the coordinate of the nearest switch a walker steps on. A Heath Kit chart recorder was used to monitor voltage. The transfer function of the recording apparatus was found to be linear (see Appendix B).

Once the data was gathered, path coverage was calculated for each subject, to test the study's hypothesis that the touch technique fails to survey all of the walker's path (100%). Since it was expected that this hypothesis would hold true, cane technique was mathematically modeled to compare with the "modified technique" proposed by Uslan and Manning (see Figure 5.).

A formula to calculate the modified technique's percentage of path coverage was prepared and computer-programmed (see Appendix C). From the geometry of Figure 6. it is evident that the safety factor (S)

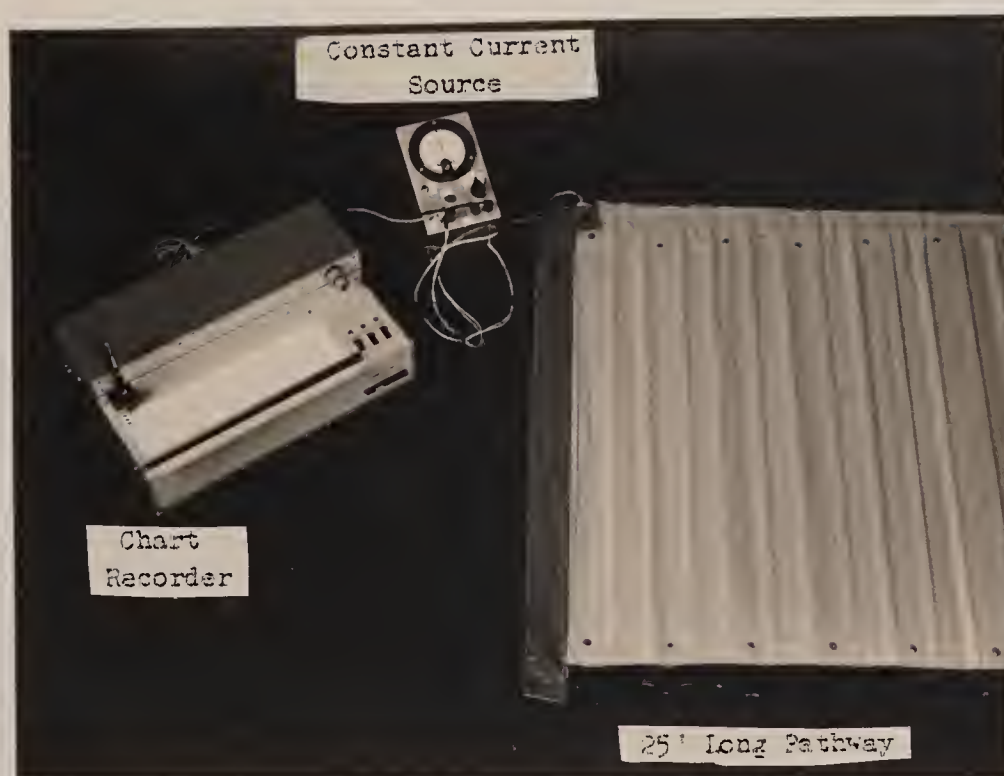
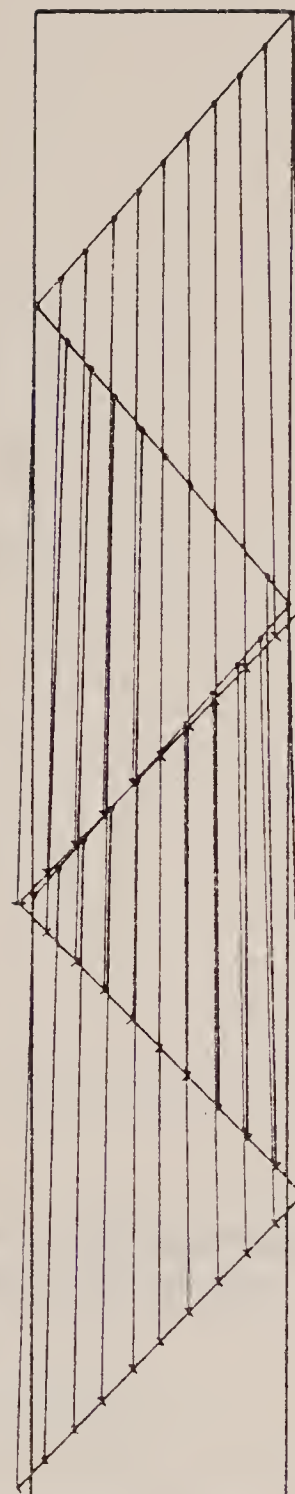


Figure 4. The apparatus used for measuring step size.



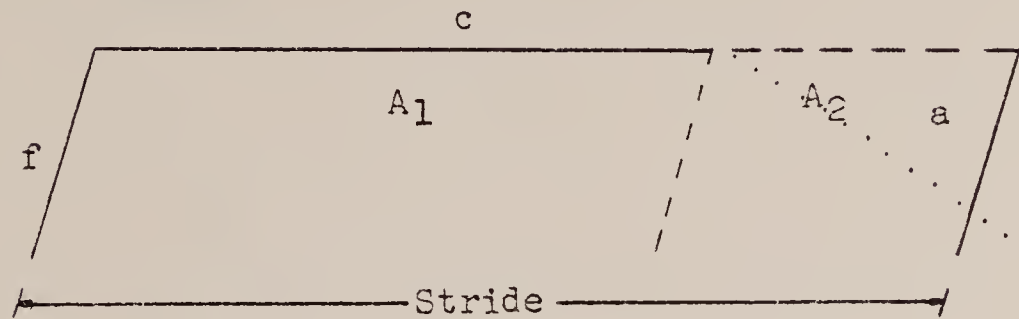
a.



b.

Figure 5. A photograph showing wrist and arm motion in the modified technique (a.). The modified technique requires that the walker swing his forearm, pivoting it from the elbow, as well as from the wrist. An orthographic projection of the author's idealized step in the modified technique shows complete coverage of the path of travel (b.).

can be given by $S = 1 - \frac{\dot{a}}{A_1 + A_2}$. Forearm length is a measurement



f = projected forearm length
 c = projected cane length
 a = area of triangle
 A_1 = area of parallelogram
 A_2 = area of parallelogram
 $\dots$ = successive positions of
the cane tip

Figure 6. Percent path coverage can be calculated from an orthographic projection of the walker's forearm (f) and cane (c) as he moves forward.

necessary to the calculations. Figures 7, 8, and 9 indicate that the modified technique is more likely to encompass full path coverage (100%) than the touch technique. It is possible that, for some subjects, path coverage cannot be comprehensive, even with the modified technique.

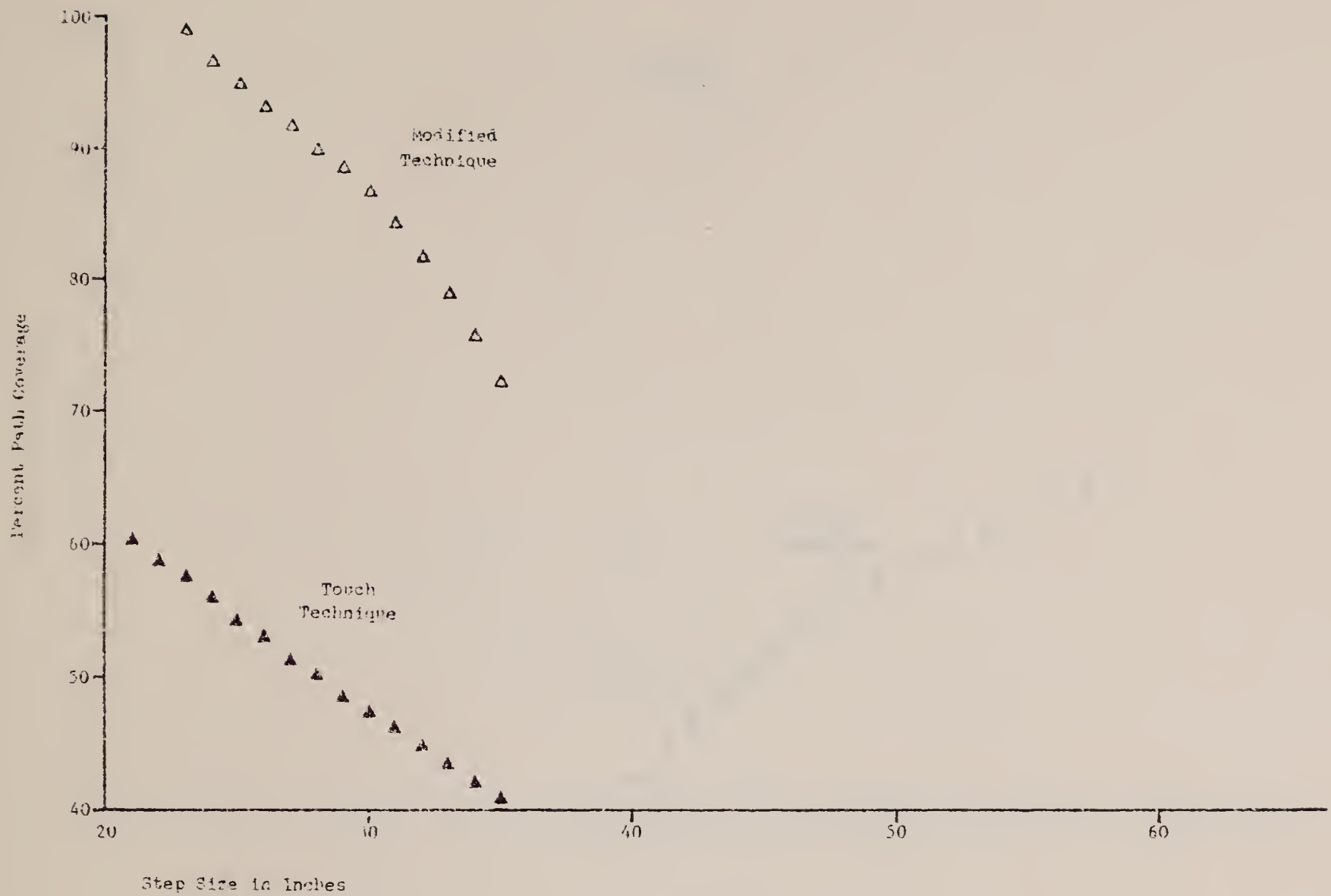


Figure 7. Percent path coverage versus step size for the touch technique and the modified technique (when CL=52, HH = 30).

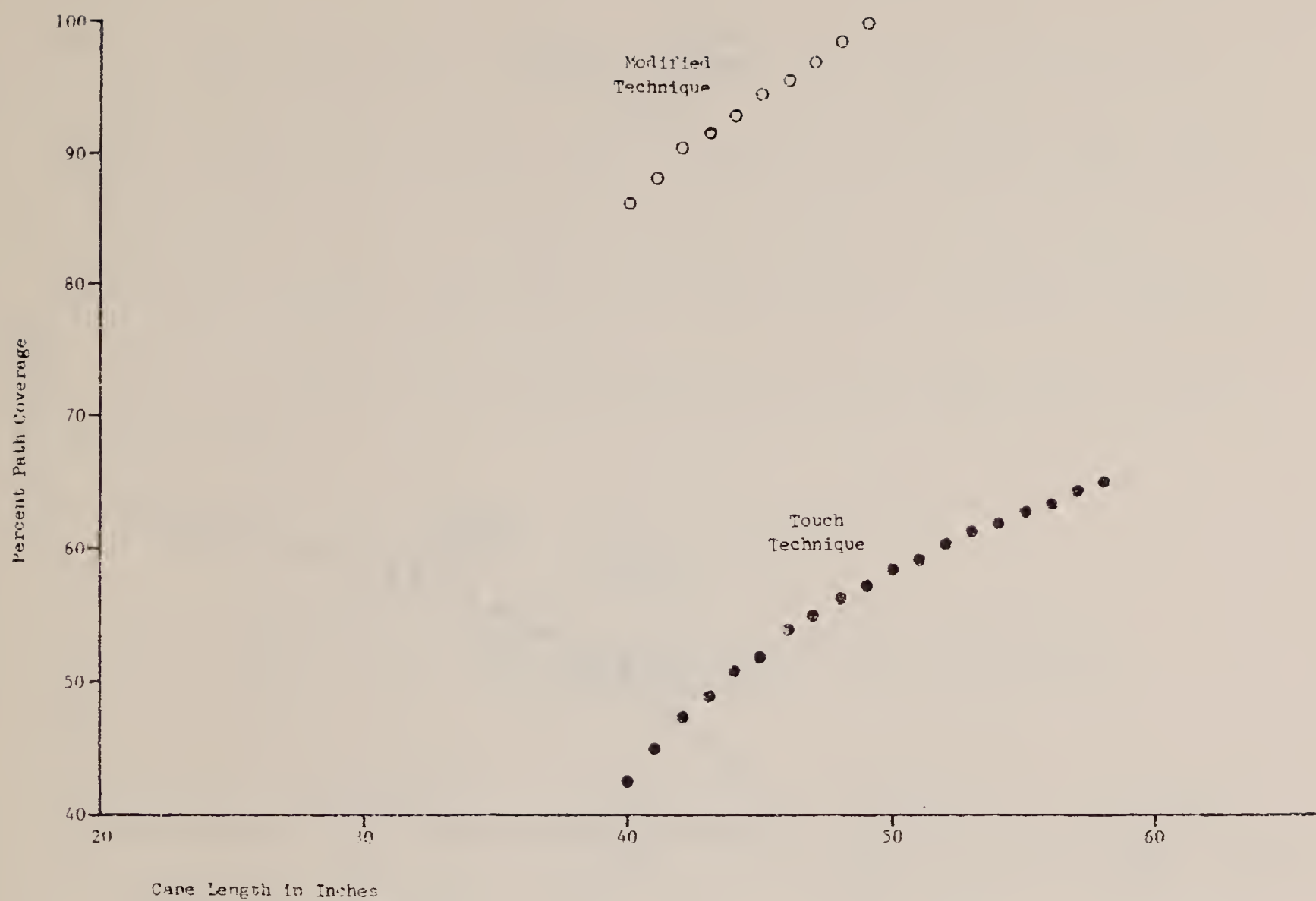


Figure 8. Percent path coverage versus cane length for the touch technique and the modified technique (when $HH = 30$, $SS = 21$).

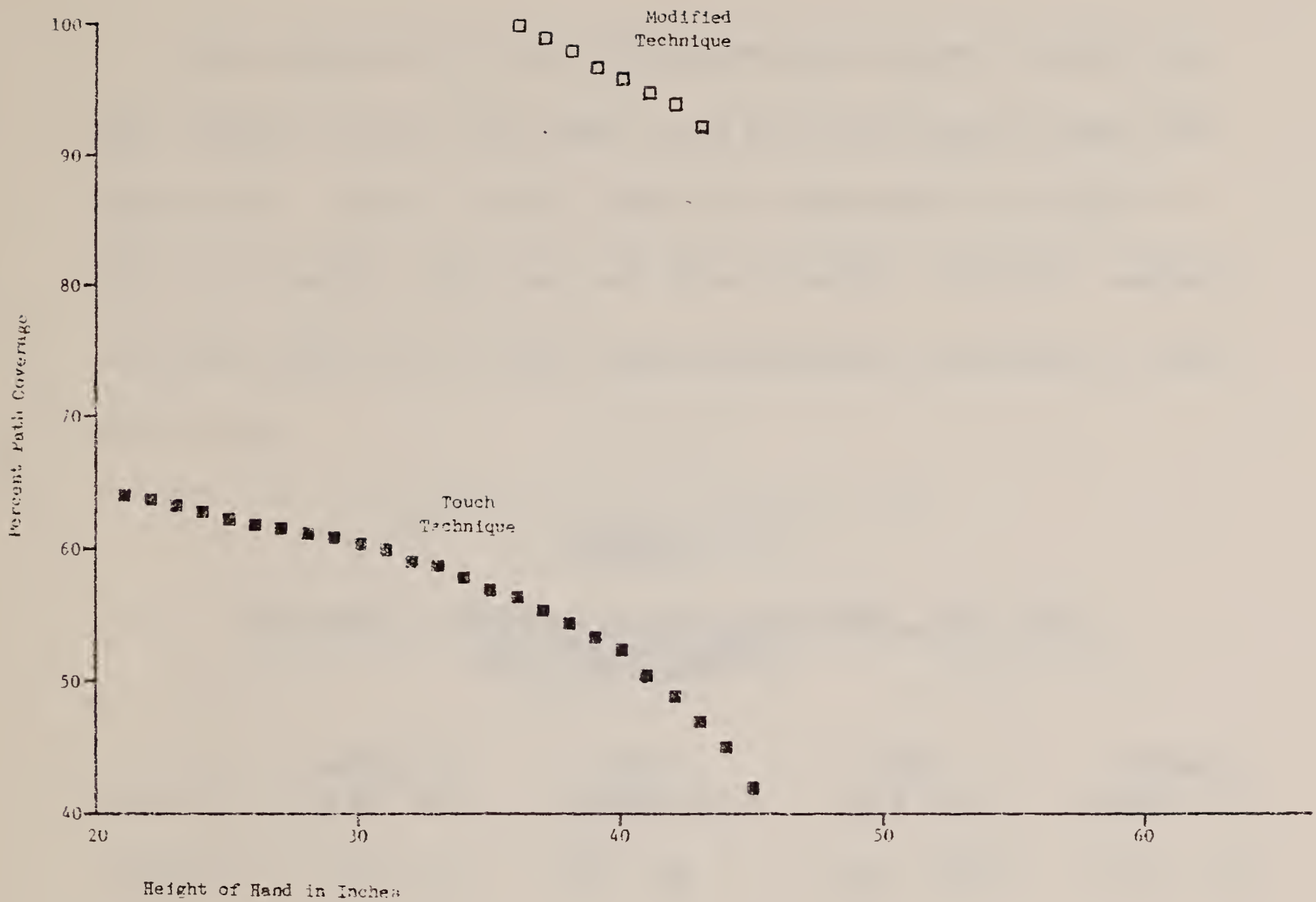


Figure 9. Percent path coverage versus height of hand for the touch technique and the modified technique (when $CL = 52$, $SS = 21$).

RESULTS

Data collected for each of the seventeen subjects included sex, age, height of hand, cane length, step size, and forearm length (see Appendix D). Table I, below, summarizes measurements of height of hand, cane length, step size, and forearm length. Subjects' tendency to shuffle their feet as they walked undoubtedly contributed to their short steps.

TABLE I

THE RANGE OF HEIGHT OF HAND, CANE LENGTH, STEP SIZE,
AND FOREARM LENGTH

SUBJECTS	HEIGHT OF HAND (IN.)	CANE LENGTH (IN.)	STEP SIZE (IN.)	FOREARM LENGTH (IN.)
13 Males	32 - 47	46 - 56	8.4 - 19.0	9.5 - 11.5
4 Females	30 - 38	45 - 46	7.5 - 13.38	6.5 - 8.5

Table II, shown below, indicates that the touch technique did not permit subjects to probe the entire path with their canes. Yet, in every

TABLE II

THE RANGE OF COVERAGE PROVIDED BY THE TOUCH TECHNIQUE
AND THE MODIFIED TECHNIQUE

SUBJECTS	% PATH COVERAGE (TOUCH TECHNIQUE)	% PATH COVERAGE (MODIFIED TECHNIQUE)
13 Males	57.75 - 76.39	100 for all S's
4 Females	67.00 - 79.74	100 for all S's

case, mathematical modeling to compare to the modified technique offered the complete protection of full path coverage and afforded subjects information about a substantial area the touch technique left beyond their survey. Table III shows that, with the modified technique, both the mean increase and the range of increase in coverage rose well above twenty-five percent.

TABLE III

INCREASE IN COVERAGE PROVIDED BY THE
MODIFIED TECHNIQUE

SUBJECTS	MEAN INCREASE IN COVERAGE (%)	RANGE INCREASE IN COVERAGE (%)
13 Males	31.86	23.61 - 42.25
4 Females	27.73	20.26 - 33.00

CONCLUSION

The concept of the idealized step proved to be a useful tool for testing the hypothesis that the touch technique does not afford full path coverage (100%). Results clearly indicate that the touch technique for cane scanning does not provide one hundred percent path coverage and that improving upon the touch technique's coverage is entirely feasible through either manipulation of subject's characteristics or use of the modified technique.

Perhaps the study's most unexpected observation is that path coverage provided by in-step and out-of-step differ very little for a particular step. However, because one cannot generalize from a single, very approximate step, research should test in-step and out-of-step through many model steps constructed accurately to differing specifications. Indeed, this thesis asserts, as a primary contention, that individual variation, especially physical characteristics, must be thoroughly considered before the touch technique is granted acceptance as a cane technique of sufficient safety.

Although the modified technique surpasses the touch technique in path-scanning ability, it is conceivable that the modified technique represents an alternative too unrealistic to be adopted. Many questions remain unanswered: Is the modified technique too difficult to learn? Is it too fatiguing? How does it affect kinesthetic sensitivity? This work should serve as a start toward the full investigation of

conventional and unconventional cane techniques -- a necessary endeavor if an approach to teaching an optimally safe technique is to be found.

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APPENDIX A

CALCULATING PATH COVERAGE FOR THE TOUCH TECHNIQUE

Symbols:

G = body width

S = safety factor (percent path coverage)

s = step size

H = height of hand

L = cane length

L' = projected cane length

x, y = co-ordinates of cane tip

x', y' = co-ordinates of a general point (any point) on the
projection of the cane when the cane is all the way
to the left for the second time.

A = area of parallelogram (total area to be sampled)

a = area of triangle (area actually sampled by cane or $\frac{1}{2}ph$)

v = velocity of walking

t = time

$\rho = vt$

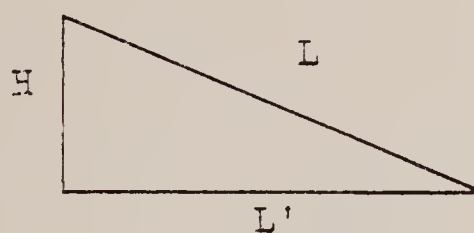
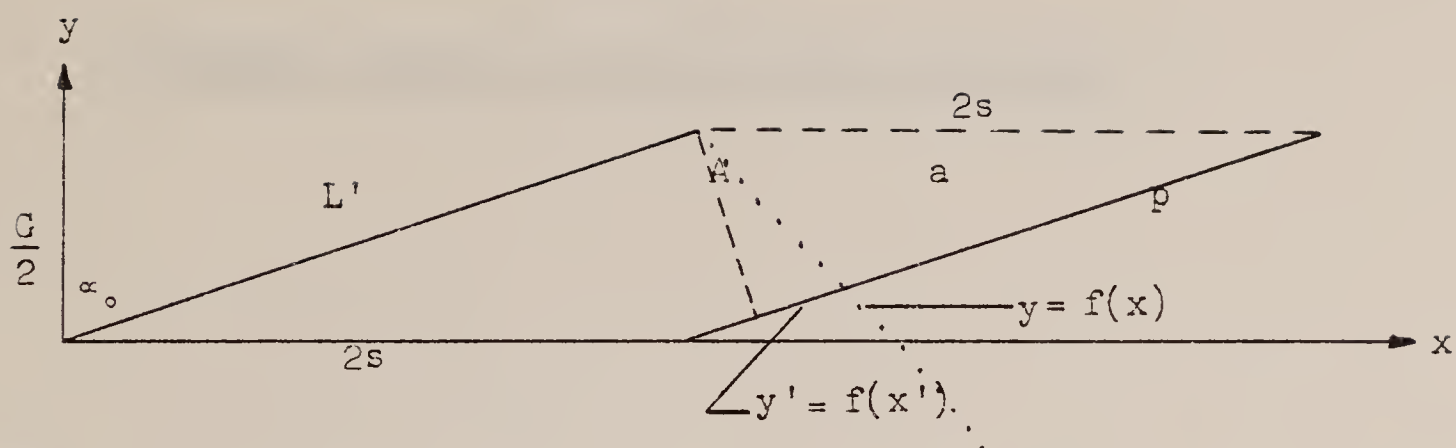
$\dots$ = successive positions of the cane tip

α = θ from y direction

α_0 = minimum value as shown

$\dot{\alpha} = \frac{d\alpha}{dt}$

"solve simultaneously" = solve for the condition $x = x'$ and $y = y'$



$$1. \quad S = 1 - \frac{a}{A} \approx 1 - \frac{p}{2L'}$$

Where $y = f(x)$ is approximately a straight line.

$$2. \quad \alpha = \alpha_0 + \dot{\alpha} t$$

$$\dot{\alpha} = \frac{(\frac{\pi}{2} - 2\alpha_0)}{S} \cdot v$$

$$3. \quad \alpha = \alpha_0 + \frac{\frac{\pi}{2} - \alpha_0}{S} \rho$$

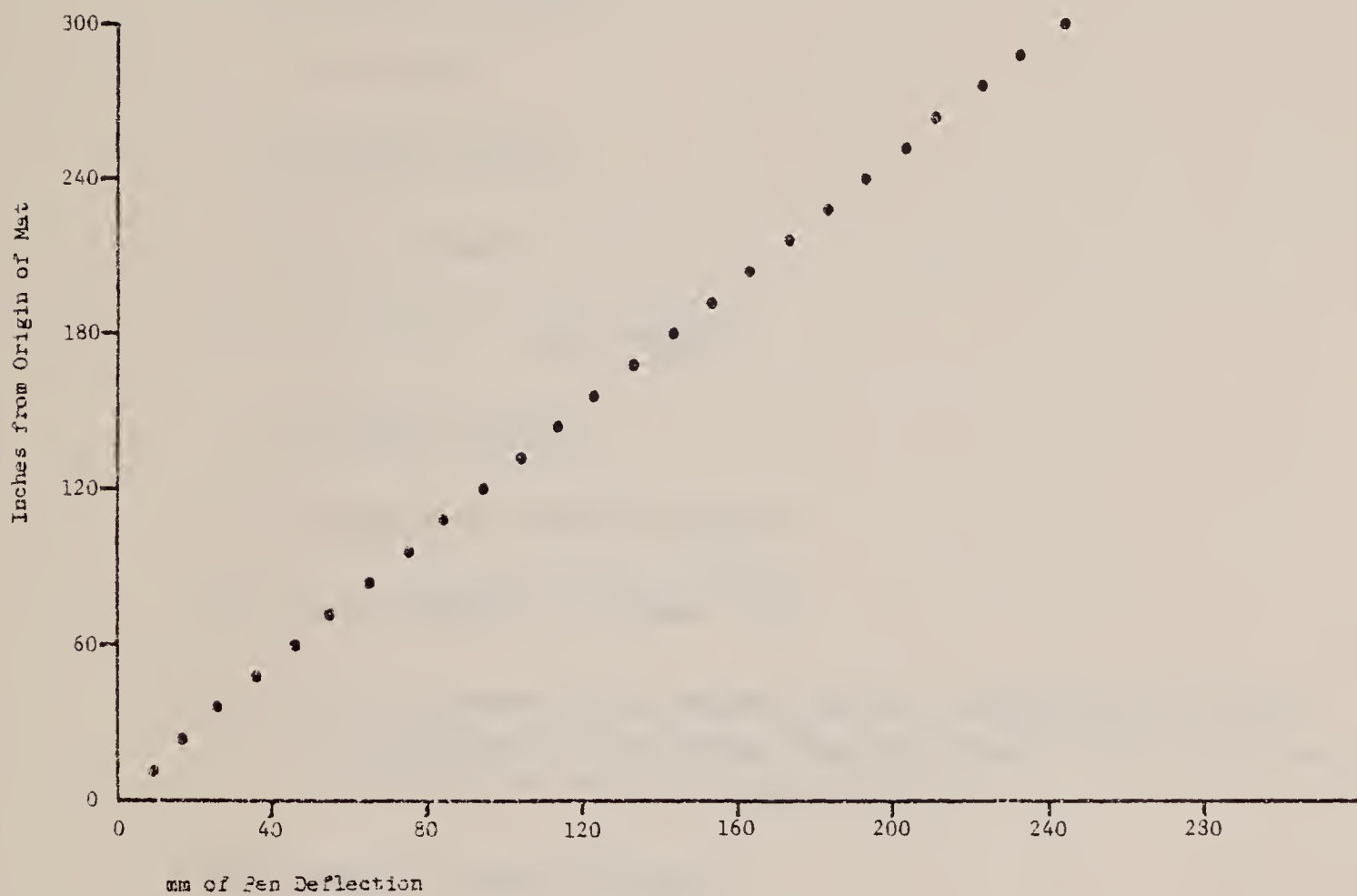
$$4. \quad y = L' \cos \alpha$$

$$5. \quad x = L' \sin \alpha + \rho$$

$$6. \quad y' = (x' - 2s) \tan \left(\frac{\pi}{2} - \alpha_0 \right)$$

} Solve Simultaneously

APPENDIX B

TRANSFER FUNCTION OF THE RECORDING APPARATUS

APPENDIX C

CALCULATING PATH COVERAGE FOR THE MODIFIED TECHNIQUE

Symbols:

G = body width

H = height of hand

s = step size

S = safety factor

L = cane length

L' = projected cane length

F = forearm length

F' = projected forearm length

x, y = co-ordinates of cane tip

x', y' = co-ordinates of a general point (any point) on the
projection of the cane when the cane is all the way
to the left for the second time.

A_1 = area of parallelogram

A_2 = area of parallelogram

a = area of triangle

v = velocity of walking

t = time

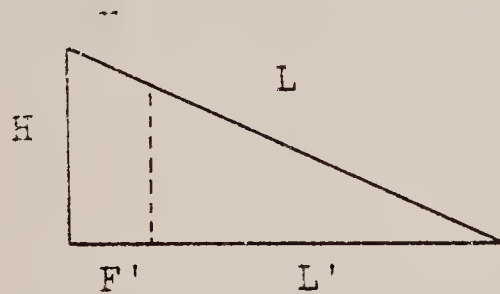
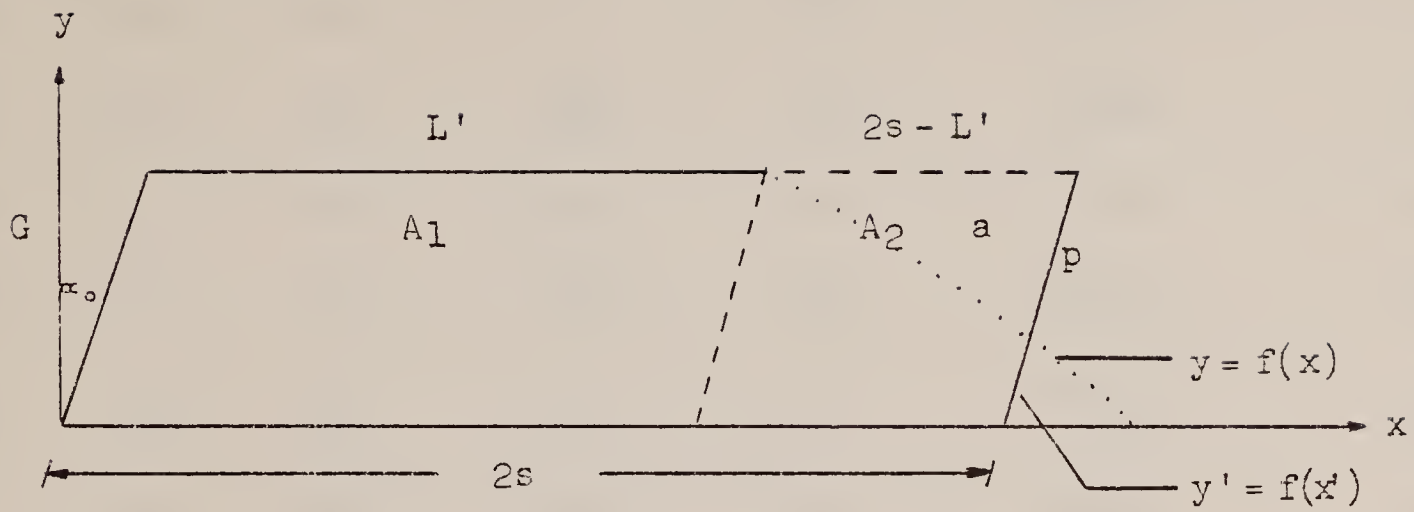
$p = vt$

$\dots$ = successive positions of the cane tip

$\alpha = \angle$ from y direction

α_0 = minimum value as shown

$$\dot{\alpha} = \frac{d\alpha}{dt}$$



$$1. \quad S = 1 - \frac{a}{A_1 + A_2} = 1 - \frac{1}{\frac{1 + A_1}{A_2}} \cdot \frac{a}{A_2}$$

$$= 1 - \frac{1}{1 + \frac{L'}{2s - L'}} \cdot \frac{P}{2F'}$$

$$2. \quad y = F' \cos \alpha + L'$$

$$3. \quad x = F' \sin \alpha + p + L'$$

$$4. \quad y' = (x' - 2s) \tan \left(\frac{\pi}{2} - \alpha_0 \right)$$

} Solve Simultaneously

APPENDIX D

DATA COLLECTED ON EACH SUBJECT

	AGE	HH(in)	CL(in)	$\bar{M}$ SS(in)	FL(in)	% COVERAGE (TT)	% COVERAGE (MT)
S1*	14	33.0	46	7.5	8.5	79.74	100
S2*	18	38.0	45	9.82	8.5	67.00	100
S3*	18	30.0	46	13.38	7.0	68.15	100
S4*	17	36.5	46	8.62	6.5	74.19	100
S5	16	33.0	48	10.33	10	74.50	100
S6	15	32.0	46	13.67	10	66.00	100
S7	18	41.0	53.5	11.6	10	71.78	100
S8	15	33.5	47	13.2	10.5	66.99	100
S9	21	40	53	15.4	11	63.84	100
S10	18	38	52	19.0	11	57.75	100
S11	17	39	52	12.5	10.5	69.56	100
S12	19	38	46	12.71	11	61.12	100
S13	17	47	56	11.67	11.5	68.21	100
S14	18	39.5	50	12.22	10	67.46	100
S15	16	34	47	12.67	10	67.75	100
S16	16	38.5	49	10.36	9.5	71.42	100
S17	17	36	47	8.4	9.5	76.39	100

* Females

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HV1707 Uslan, Mark M.
Us5 Cane technique: toward
more complete path
coverage.

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15 WEST 16th STREET
NEW YORK, N.Y. 10011

